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Mapping of water catchment area using GIS in Majalengka Regency, West Java

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Abstract. Water catchment area is basically not to be exploited excessively. It will turn soil into faults which won't be able to hold rain water. Thus, soil which was categorized as fertile turned into arid land and its nutrients content decreased. Forests and water catchment damage potentials areas in Majalengka increased rapidly, in line with the medium-long term development plan. This research aimed to map the water catchment in Majalengka. The research was conducted in Majalengka from February to March 2018. The method used in the study was a survey with technical implementation of map overlaying and scoring using a Geographic Information System (GIS). The data used were secondary data. The data used were the Map of Land Use, Map of Precipitation 2013-2017, Map of Soil Texture, Map of Land Slope and Spatial Planning and Administration (RTRW) of Majalengka 2011-2031 Majalengka Regency 2011-2031. The results showed that Majalengka has three suitability classes of water catchment area, which are quite suitable, less suitable and not suitable. The suitability classes of water catchment area in Majalengka is as follows: (a) 39739.92 ha of quite suitable class, (b) 66233.30 ha of less suitable class and (c) 14450.88 ha of not suitable class.

1. Introduction

The water catchment area basically cannot be exploited excessively because it will turn the fertile and stable soil structure into faults which will not be able to hold water when it rains. As a result, the soil that previously could be categorized as fertile becomes arid and has the content of nutrients reduced; especially the humus which will be increasingly lost. The land used for water catchment areas is the land planted with various kinds of vegetation that can resist erosion [1].

The potential for destruction of forest and water catchment areas in Majalengka Regency is increasing in line with the medium and long-term plan of the Regency. Based on regional planning, the Kertajati District area is intended for the construction of the West Java International Airport (Bandara Internasional Jawa Barat). Consequently, it is estimated that there will be new buildings appear upon the completion of the BIJB such as hotels, shopping centers and settlements that have the potential to damage water catchment areas. Although there are already provisions in the Spatial Detail Plan (RDTR), there is no physical tool like a map that can facilitate the designation of location. This will have an impact on the need for clean water in the long run and on areas that are prone to flood and landslides. Within the Spatial Plan, it is only revealed that 75% of the southern part of Majalengka in the form of hills and mountains is designated as a water catchment area.

Based on the description above, efforts are needed to handle land transfer activities in water catchment areas so that the development of built-up land can be restricted, and water catchment areas



such as forests and agriculture can be maintained for the preservation of water catchment areas. The threat for water catchment area is one of the adverse aspects to the community, in terms of built-up area, the area of location permit that has not yet been completed, and the population density in each district, as well as the efforts required to preserve water catchment areas.

Mapping of water catchment areas has not been widely carried out in Indonesia, especially in Majalengka which has never been done before. Mapping is usually done for landslide-prone, flood-prone and erosion-prone areas. Making a map of the water catchment area of Majalengka Regency can be used as a reference to avoid massive land transfer. The map was made using a GIS (Geographic Information System) application which is a graphical information system utilizing maps. This can be used as a planning in agriculture.

Regarding this issue, the problem was formulated, which is on the construction of the West Java International Airport in Kertajati District, Majalengka Regency affecting other development in Majalengka Regency area related to land use, one of which is in the water catchment area. Therefore, efforts are required to maintain the rainwater catchment area in Majalengka so as not to deviate the land function, one of which is through map making. This study aimed to map the water catchment area in Majalengka Regency.

2. Methods

The method used in this study was the observation method. Selection of observation locations was by purposive method. Data and information obtained from the data collection stage were analyzed descriptively and spatially. Spatial analysis was conducted using maps overlay and scoring. Spatial analysis with overlays from this thematic map included maps of administration, maps of land use, maps of 2013-2017 rainfall, maps of soil texture and maps of land slope. Spatial analysis and scoring were carried out to determine the zoning of the water catchment area in Majalengka Regency, West Java Province.

Water catchment area is an area where rainwater seeps into the soil and becomes groundwater [2, 3, 4]. According to Minister of Public Works No. 02 of 2013 [5], concerning Guidelines for Preparation of Water Resources Management Plans, to determine the location and boundaries of water catchment areas in an area, a spatial analysis of water catchment areas is needed, with the review of each several spatial parameters, which are land use, rainfall, soil texture and land slope, water catchment area.

2.1. Land use

In parameter scoring value, land use obtained a higher scoring value that was 40% compared to other parameters. This is because the parameters of land use greatly affect the ability to absorb water into the soil, the capabilities of basic vegetation and top soil conditions that are rich in organic matter and humus are very effective in absorbing water into the soil [6].

Table 1. Land use parameters

Spatial Classification	Score	Category	Spatial Criteria
Forest	5	Very High	Areas with forest land use will have a higher water absorption capability compared to areas that have settlement land use
Shrubs	4	High	
Farm/Garden	3	Medium	
Rice Field/Swamps	2	Low	
Settlement / Buildings	1	Very Low	

Source: Government Regulation No. 02 of 2013 [5] concerning Guidelines for Preparing Water Resources Management (with table modification)

The transfer of land use makes it difficult for land surface to absorb water causing the falling rainwater hard to penetrate into the soil. Rainwater will stagnate and floods occur. The development of land use with low level of infiltration will trigger problems in the management of water in an area.

2.2. Rainfall

Rainfall parameters (**Table 2**) had a score of 30%, Rainfall is the object studied because the main concern here is regarding water absorption into the soil; It makes this parameter is so important as its function cannot be replaced by other parameters, so this parameter has an important role because its function cannot be replaced by other parameters.

Rainfall data were obtained from rain measurement data on stations in the study area covering all study areas. In connection with this matter, the factor of rain infiltration is calculated as follow:

$$RD = 0.01.P.Hh$$

Description:

RD = factor of rain infiltration

P = bulk annual rainfall

Hh = number of rainy days each year

(Source: Wibowo, 2006)

Table 2. Rainfall parameters

Spatial Classification	Score	Category	Spatial Criteria
>3000 mm/yr	5	Very High	Areas with high rainfall (> 3000 mm / yr) will have a higher absorption potential compared to areas with low rainfall (<500 mm / yr).
2000-3000 mm/yr	4	High	
1000-2000 mm/yr	3	Medium	
500-1000 mm/yr	2	Low	
<500 mm/yr	1	Very Low	

Source: Director General of Reforestation and Land Rehabilitation, 1998.

2.3. Soil texture and land slope

Soil texture and land slope had the same weight of respectively 15%. Sandy soil has large pores so that water is easier to enter into the soil, while clay soil has small pores making it difficult for water to enter the soil. The greater the slope, the smaller the amount of water absorbed. Soil texture parameters can be seen in **Table 3** and the land slope parameters can be seen in **Table 4**.

Table 3. Soil texture parameters

Spatial Classification	Score	Category	Spatial Criteria
Sand	5	Very High	Areas that have soil texture in the form of sand will have a higher water absorption ability compared to areas that have soil texture in the form of clay.
Loamy Sand	4	High	
Sandy Loam	3	Medium	
Silty Loam	2	Low	
Clay	1	Very Low	

Source: Public Works Government Regulation No. 02 Year 2013 on Guidelines for Management Planning of Water Resources (with modifications)

Table 4. Slope parameters

Spatial Classification	Score	Category	Spatial Criteria
<5%	5	Very High	Areas with Slope Flat land (<5%) will have a higher water absorption capability compared to steep terrain.
5-15%	4	High	
15-30%	3	Medium	
30-45%	2	Low	
>45%	1	Very Low	

Source: Director General of Reforestation and Land Rehabilitation, 1998.

2.4. Water catchment area

Map of water catchment area was obtained from the scoring and overlapping process of thematic maps (overlay) of the maps of land use, rainfall, soil texture and land slope. Classification of criteria for the conditions of water catchment area was obtained through scoring method, which is the sum of times between the value and weight of each parameter, using the formula:

$$\text{Total Value} = (\text{Weight} \times \text{Land use Score}) + (\text{Weight} \times \text{Rainfall Score}) + (\text{Weight} \times \text{Soil Texture Score}) + (\text{Weight} \times \text{Slope Score})$$

Table 5. Classification of water catchment area

Category	Score
Suitable	4,60-5
Quite Suitable	3,60-4,50
Less Suitable	2,60-3,50
Not Suitable	<2,60

Source: Government Regulation No 02 of 2013 concerning Guidelines for Preparing Water Resources Management Plans (with modifications)

3. Results and discussions

Table 7 shows that in 2013 the most dominant land use in Majalengka was rice field/swamp/water covering an area of 41,786 ha, while land use was the least used for settlement. In 2017 land use was dominated by fields/gardens covering 47,302 ha, while the least was used for settlement 12,174 ha.

Table 6. Land use in Majalengka (ha) Year 2013-2017

Land use Types	2013	2014	2015	2016	2017
Forest	26.720	12.274	11.066	11.940	13.513
Shrubs	10.349	15.237	20.436	31.509	15.413
Field /Gardens	33.771	41.943	33.438	26.458	47.302
Rice Field/Swamp/Water	41.786	37.047	42.450	36.723	32.022
Settlement / Buildings	7.798	13.923	13.034	13.794	12.174

Table 7. Scoring result of land use parameter, 2013

Spatial Criteria	Spatial Classification	Score	Weight	Total Score	Area (Ha)	Category
Areas with forest land use will have a higher water catchment capability compared to areas of settlement.	Forest	5	40%	2	26.720	Very High
	Shrubs	4	40%	1.6	10.349	High
	Field /Gardens	3	40%	1.2	33.771	Medium
	Rice Field/Swamp/Water	2	40%	0.8	41.786	Low
	Settlement / Buildings	1	40%	0.4	7.798	Very Low
	Research Area				120.424	

The land in Majalengka Regency, in 2013, was dominated by rice fields covering 41,786 ha, with a total score of 0.8 in the low category. The least land use was settlement of 7,798 ha in a very low category. The map of Land Use in 2013 can be seen in **Figure 1**. Land use in Majalengka Regency in 2013 was dominated by low class covering 41,786 ha, mostly located in the northern part of Majalengka Regency. Map of Land Use Class in 2013 can be seen in **Figure 2**.

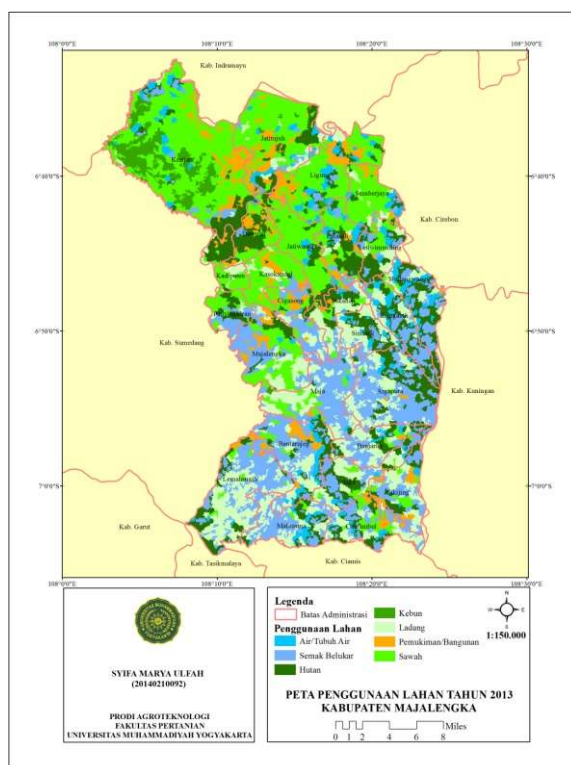
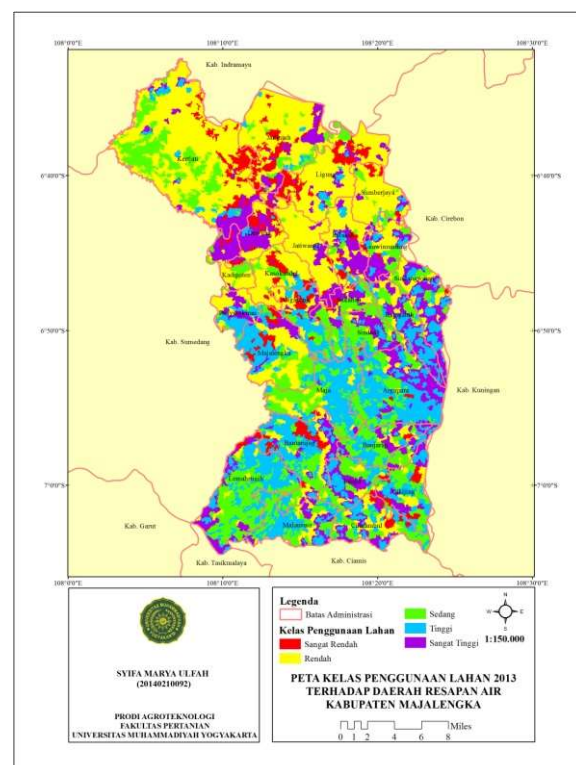
Table 8. Scoring result of land use parameter, 2014

Spatial Criteria	Spatial Classification	Score	Weight	Total Score	Area (Ha)	Category
Areas with forest land use will have a higher water catchment capability compared to areas than settlement.	Forest	5	40%	2	12.274	Very High
	Shrubs	4	40%	1,6	15.237	High
	Field /Gardens	3	40%	1,2	41.943	Medium
	Rice Field/Swamp/Water	2	40%	0,8	37.047	Low
	Settlement / Buildings	1	40%	0,4	13.923	Very Low
	Research Area				120.424	

Based on **Table 8**, Majalengka Regency is dominated by fields and gardens of 41.943 ha with a total score of 1.2 in medium categories. The least land use was the forest with an area of 12,274 ha. The map of land use in 2014 can be seen in **Figure 3**. The land use of Majalengka District in 2014 was dominated by the middle class which was 41,943 ha, the class was spread throughout the research area, but the most were spread in the southern part of Majalengka Regency as can be seen in **Figure 4**.

Table 9. Scoring result of land use parameter, 2015

Spatial Criteria	Spatial Classification	Score	Weight	Total Score	Area (Ha)	Category
Areas with forest land use will have a higher water catchment capability compared to areas of settlement.	Forest	5	40%	2	11.066	Very High
	Shrubs	4	40%	1,6	20.436	High
	Field /Gardens	3	40%	1,2	33.438	Medium
	Rice Field/Swamp/Water	2	40%	0,8	42.450	Low
	Settlement / Buildings	1	40%	0,4	13.034	Very Low
	Research Area				120.424	

**Figure 1.** Map of land use in 2013**Figure 2.** Land use in 2013 on water catchment area

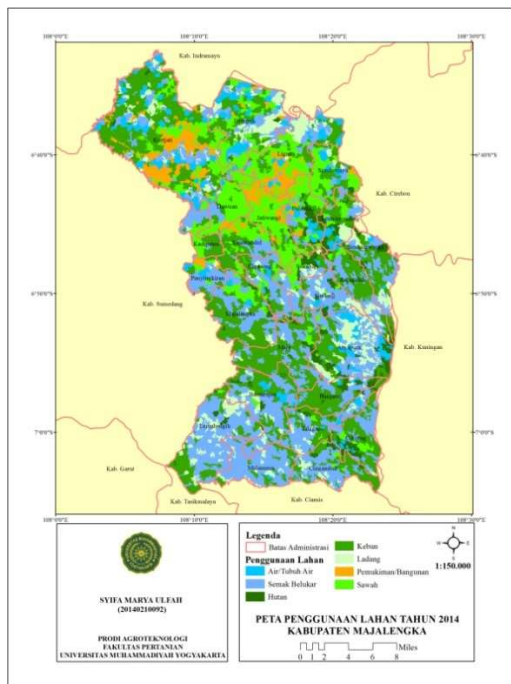


Figure 3. Map of land use in 2014

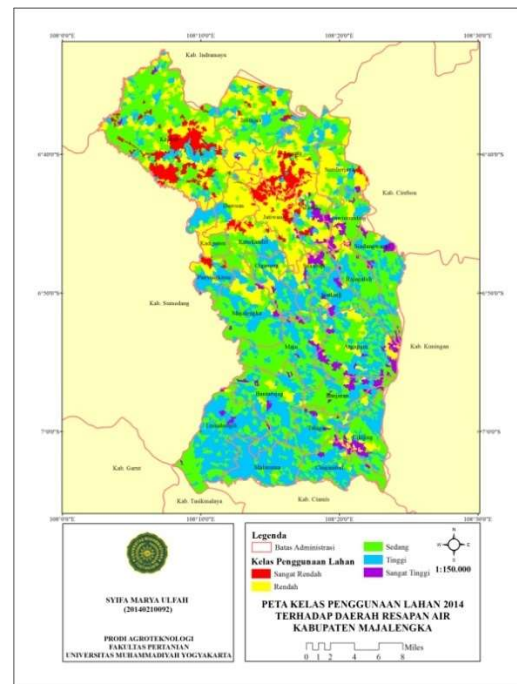


Figure 4. Land use in 2014 on water catchment area

Based on **Table 10**, Majalengka Regency is dominated by rice fields covering 42,450 ha, a total score of 0.8 in low category. The least land use was the forest with an area of 11,066 ha in a very high category. Land Use in 2015 can be seen in **Figure 5**. The land use in Majalengka Regency in 2015 was dominated by low class, covering an area of 42,450 ha, which was spread throughout the study area, but the most were widespread in the northern part of Majalengka Regency as can be seen in **Figure 6**.

Table 10. Scoring result of land use parameter 2016

Spatial Criteria	Spatial Classification	Score	Weight	Total Score	Area (Ha)	Category
Areas with forest land use will have a higher water catchment capability compared to areas of settlement.	Forest	5	40%	2	11.940	Very High
	Shrubs	4	40%	1,6	31.509	High
	Field /Gardens	3	40%	1,2	26.458	Medium
	Rice Field/Swamp/Water	2	40%	0,8	36.723	Low
	Settlement / Buildings	1	40%	0,4	13.794	Very Low
	Research Area				120.424	

Majalengka Regency is dominated by rice fields covering 36,723, with a total score of 0.8 in low category (**Table 11**). The least land use was the settlement with an area of 11,940 in a very low category. The map of land use in 2016 can be seen in **Figure 7**. The land use in Majalengka Regency in 2016 was dominated by low class, covering an area of 36,723 ha; the low class was spread throughout the study area, but most were spread in the northern part of Majalengka (**Figure 8**).

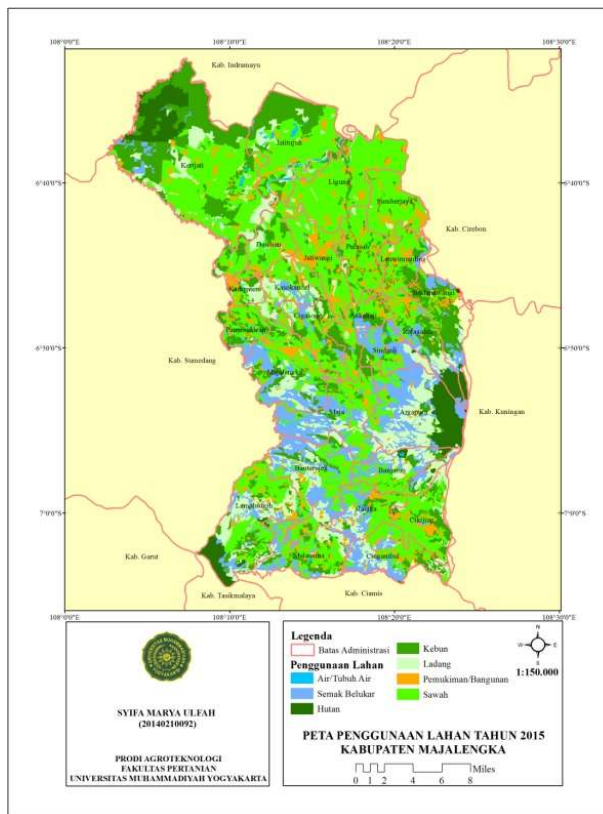


Figure 5.Map of land use in 2015

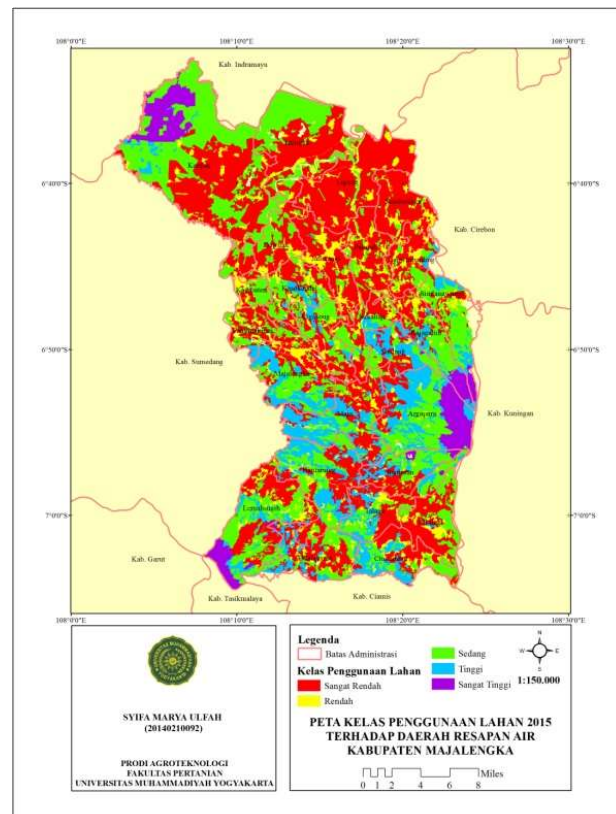


Figure 6. Land use in 2015 on water catchment area

Table 11. Scoring result of rainfall parameters

Spatial Criteria	Spatial Classification	Score	Weight	Total Score	Area (Ha)	Category
Area with high rainfall (> 3000 mm / year) will have a higher potential of absorption compared to areas with low rainfall (< 500 mm / yr)	>3000 mm/yr	5	30%	1,5	0	Very High
	2000-3000 mm/yr	4	30%	1,2	20.227	High
	1000-2000 mm/yr	3	30%	0,9	100.197	Medium
	500-1000 mm/yr	2	30%	0,6	0	Low
	<500 mm/yr	1	30%	0,3	0	Very Low
	Research Area				120.424	

Table 12. Scoring result of lands parameter 2017

Spatial Criteria	Spatial Classification	Score	Weight	Total Score	Area (Ha)	Category
Areas with forest land use will have a higher water catchment capability compared to areas than settlement.	Forest	5	40%	2	13.513	Very High
	Shrubbs	4	40%	1,6	15.413	High
	Field /Gardens	3	40%	1,2	47.302	Medium
	Rice Field/Swamp/Water	2	40%	0,8	32.022	Low
	Settlement / Buildings	1	40%	0,4	12.174	Very Low
	Research Area				120.424	

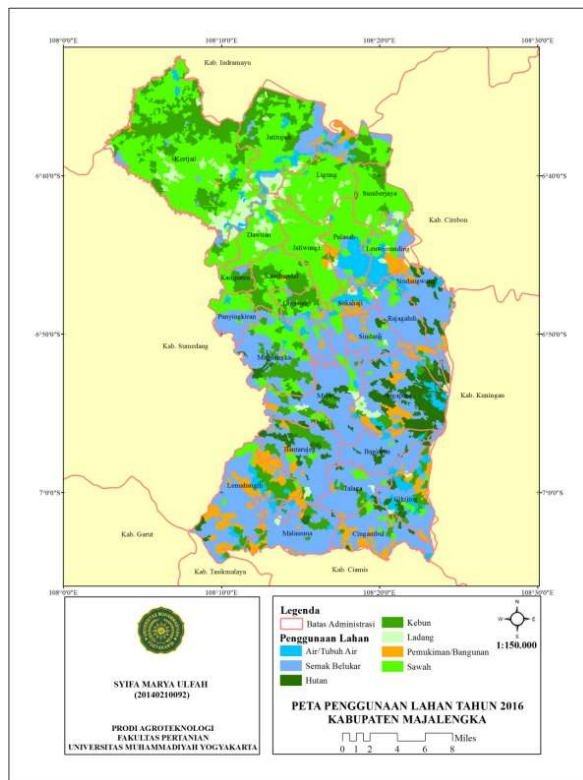


Figure 7. Map of land use in 2016

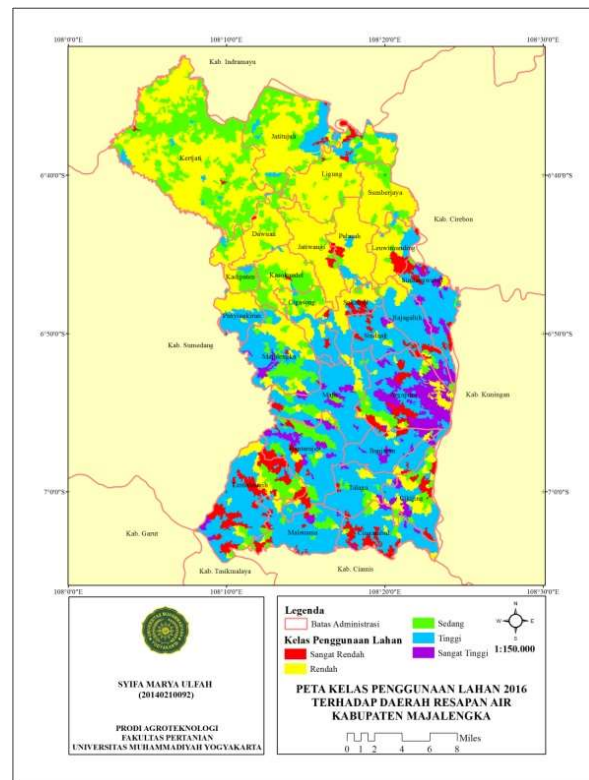


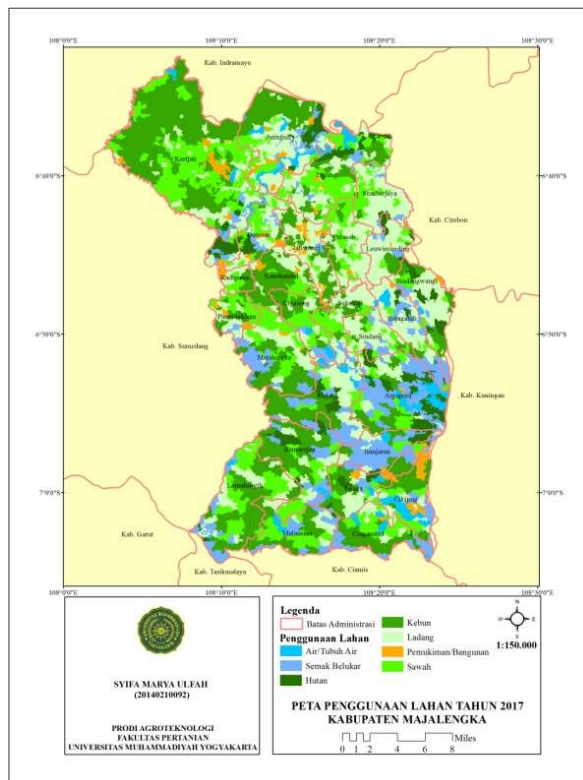
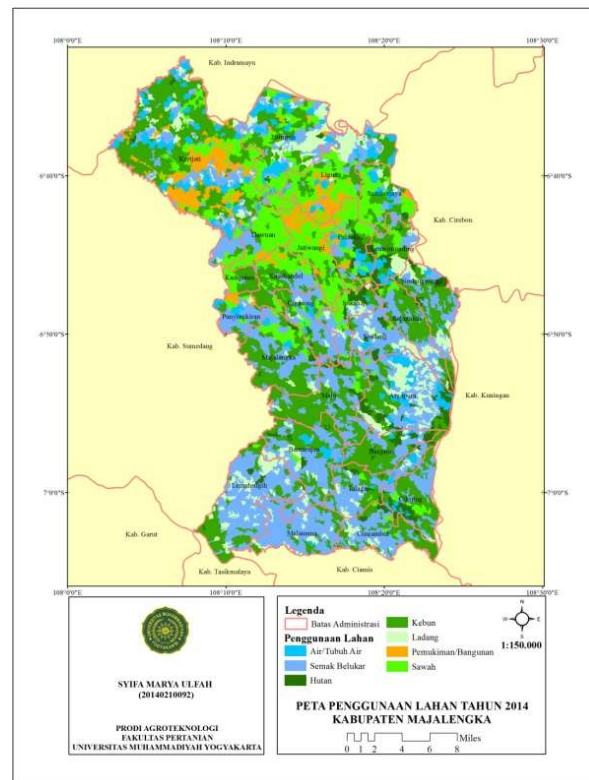
Figure 8. Land use in 2016 on water catchment area

Based on **Table 12**, Majalengka Regency is dominated by fields and gardens covering 47,302 ha, with a total score of 1.2 in medium category. The least land use was the settlement with an area of 12,174 ha in a very low category. The map of land use for 2017 can be seen in **Figure 9**. The land use of Majalengka Regency in 2017 was dominated by medium class, which was 47,302 ha; this class was spread throughout the research area as can be seen in **Figure 10**.

Table 12 shows that most of Majalengka Regency has medium rainfall which is 1000-2000 mm/year with a total score of 0.9 in the medium category with an area of 100,197 ha, Regions with the rainfall of 2000-3000 mm/year are classified high or suitable as water catchment area. The map of rainfall can be seen in **Figure 11**. Rainfall in Majalengka Regency was dominated by the medium class which is 100,197 ha; the class was spread throughout the research area as can be seen in **Figure 12**.

Table 13. Scoring result of soil texture parameters

Spatial Criteria	Spatial Classification	Score	Weight	Total Score	Area (Ha)	Category
Areas that have soil texture in the form of sand will have a higher water absorption ability compared to areas that have soil texture in the form of clay.	Sand	5	15%	0,75	15.812	Very High
	Loamy Sand	4	15%	0,6	28.731	High
	Sandy Loam	3	15%	0,45	24.623	Medium
	Silty Loam	2	15%	0,3	0	Low
	Clay	1	15%	0,15	51.258	Very Low
	Research Area				120.424	

**Figure 9.** Map of land use in 2017**Figure 10.** Land use in 2017 on water catchment area

Based on **Table 13** Majalengka Regency is dominated by clay soil texture, in very low category with a total score of 0.15 covering 51,258 ha. A map of soil texture can be seen in **Figure 13**. The soil texture of Majalengka Regency was dominated by very low class, covering an area of 51,258 ha; very low class was spread throughout the research area as can be seen in **Figure 14**.

Table 14. Scoring result of slope parameters

Spatial Criteria	Spatial Classification	Score	Weight	Total Score	Area (Ha)	Category
Areas with flat slope (<5%) will have a higher water absorption ability compared to steep areas.	<5%	5	15%	0,75	19.374	Very High
	5-15%	4	15%	0,6	38.217	High
	15-30%	3	15%	0,45	48.334	Medium
	30-45%	2	15%	0,3	14.497	Low
	>45%	1	15%	0,15	2	Very Low
Research Area					120.424	

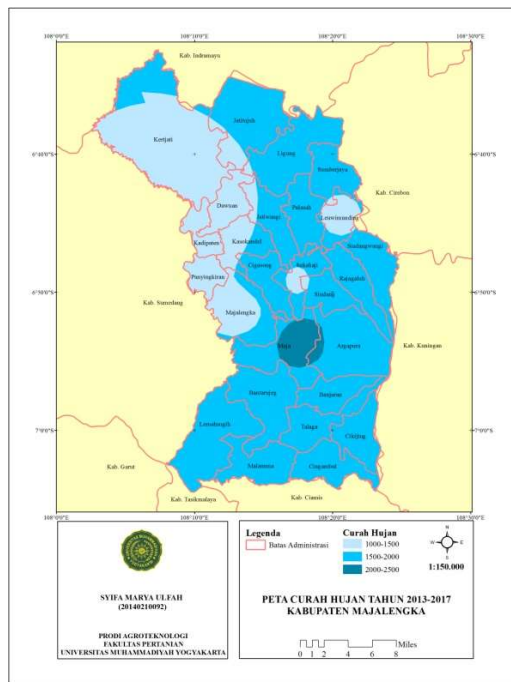


Figure 11. Map of Rainfall in 2013-2017

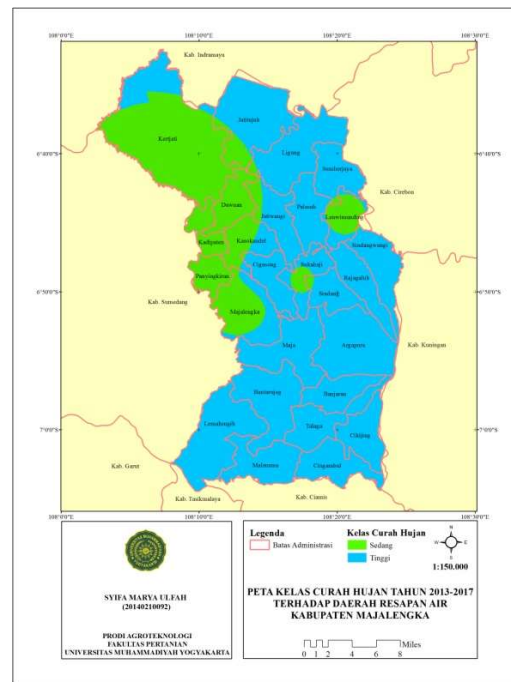


Figure 12. Rainfall map on water catchment area

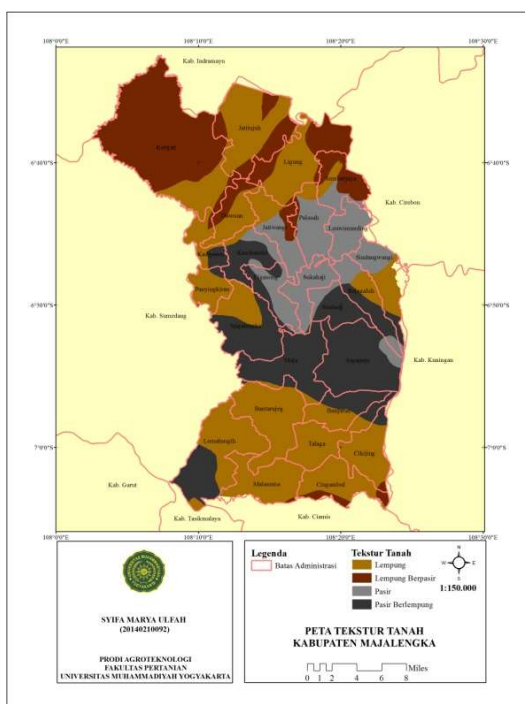


Figure 13. Map of soil texture

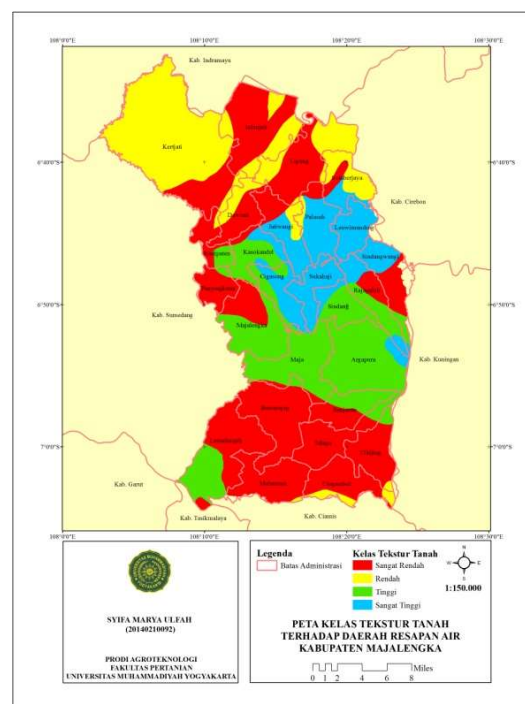


Figure 14. Map of soil texture on water catchment area

Based on **Table 14** the study area was dominated by a slope of 15-30% with an area of 48,334 ha with a score of 0.45 having a medium category. While the slope of $> 45\%$ with a very low category had a score of 0.15. The slope can be seen in **Figure 15**. The slope of the land in Majalengka Regency is dominated by the medium class, which is 48,334 ha, the middle class is spread throughout the study area, but the most were spread in the northern part of Majalengka Regency as can be seen in **Figure 16**.

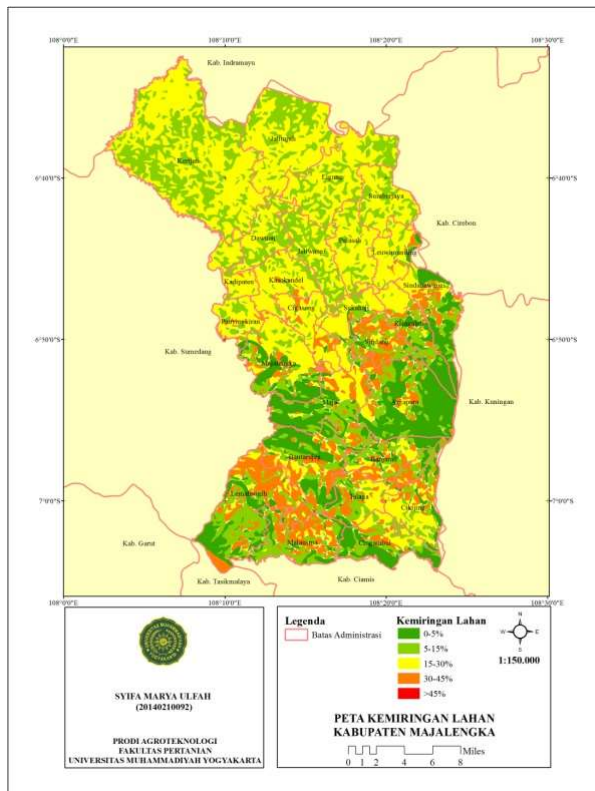


Figure 15. Map of land slope

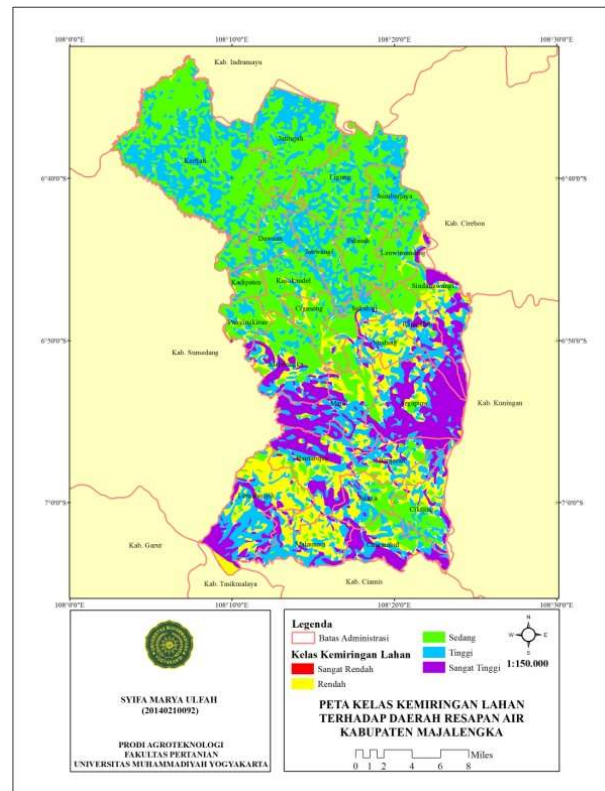


Figure 16. Map of land slope on water catchment area

Table 15. Suitability class of water catchment areas

Suitability Classes	Total Score	Area (Ha)
Suitable	4,60-5	0
Quite Suitable	3,60-4,50	39.739,92
Less Suitable	2,60-3,50	66.233,30
Not Suitable	<2,60	14.450,88

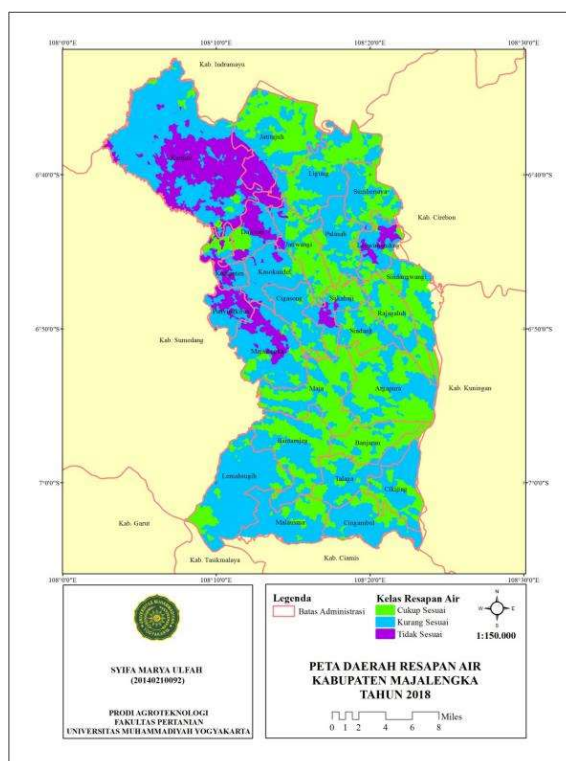
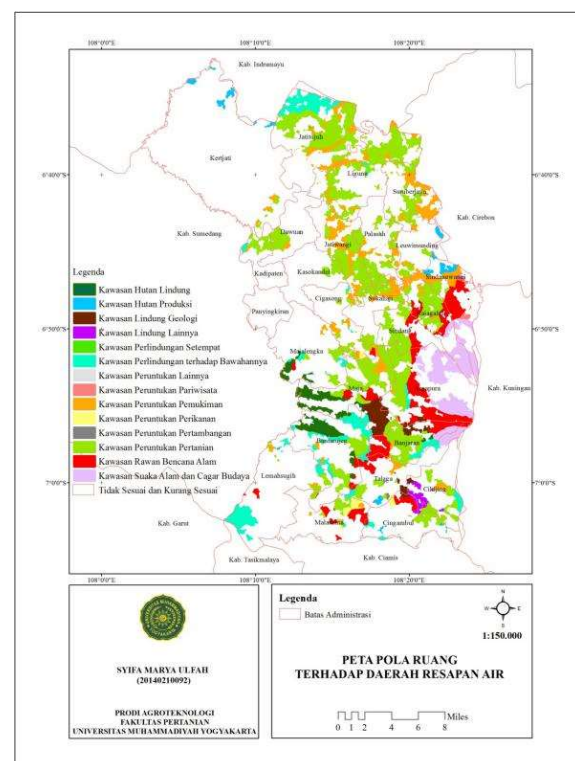
The suitability class of water catchment area in Majalengka Regency is dominated by suitability class of less suitable with a score of 2.60-3.50 covering an area of 66,233.30. Map of the Water Catchment Area of Majalengka Regency can be seen in **Figure 17**.

Table 16. Comparison of spatial patterns to water catchment area

Type of Area	Area (ha)	Real Extent (ha)	Percentage (%)
Not Suitable and Less Suitable	105.973,10		
Natural Reserve and Cultural Reserves	3.507,10	6800,00	51
Natural Disaster-Prone Areas	5.196,37	18055,00	29
Agricultural Areas	17.309,45	41281,00	42
Mining Areas	33,59	1724,00	2
Fisheries Areas	513,45	2519,00	20
Settlement Area	8.509,89	13455,00	63
Tourism Areas	87,71		
Other	1,05		
Protected Area against Subordinates	4.219,94	21877,15	19
Local Protection Areas	11,88		
Other Protected Areas	386,03	5000,00	7,7
Geological Protected Areas	1.137,63	12437,00	9
Production Forest Areas	746,10	5402,37	14
Protected Forest Areas	1.934,61	5402,00	36

In **Table 16** it can be seen that the most extensive space pattern that can be used for water catchment areas is the agricultural designation area with an area of 17,309.45 ha or 42% of the area of the actual agricultural designation. The smallest space area to function as a water catchment area is the mining designation area with an area of 33.59 ha or 2% of the area of the actual mining designation.

Kertajati District, as stated in the Spatial Plan is functioned as an industrial area, production forest, agricultural designation and other designation areas. Therefore, the development of the BIJB will not cause the disappearance of the potential for water catchment areas if the authorized parties stick to the Spatial Plan. Space pattern map of water absorption areas can be seen in **Figure 18**.

**Figure 17.** Water catchment area on Majalengka Regency**Figure 18.** Map of space patterns on water catchment area

4. Conclusion

Based on spatial analysis and scoring result of parameters of Land Use, Rainfall, Soil Texture, and Land Slope, the conclusions are map of the catchment area of Majalengka Regency was in suitability class of quite suitable with an area of 39,739.92; suitability class of less suitable with an area of 66,233.30 ha; and suitability class of not suitable with an area of 14,450.88 ha. The dominant water catchment area is the agricultural area of 17,309.45 ha (42% or agricultural land as a whole).

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